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Non-hotspot volcano chains produced by migration of shear-driven upwelling toward the East Pacific Rise

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While most oceanic volcanism is associated with the passive rise of hot mantle beneath the spreading axes of mid-ocean ridges (MOR), volcanism occurring off-axis reflects intraplate upper-mantle dynamics and composition, yet is poorly understood. Close to the East Pacific Rise (EPR), active magmatism propagated towards the spreading center to create a series of parallel volcanic ridges on the Pacific Plate (of length ∼3500 km for the Pukapuka, and ∼500 km for the Sojourn, and Hotu-Matua ridges). Propagation of this volcanism by ∼20 cm/a, as well as asymmetry in a variety of geophysical observables across the EPR, indicates strong lateral eastward pressure-driven flow in the asthenosphere that is driven by upwelling beneath the South Pacific Superswell [1]. Although this pattern of large-scale mantle flow can account for the propagation of intraplate melting towards the EPR, it does not explain decompression melting itself.
We hypothesize that shear-driven upwelling sustains off-axis volcanism. Shear-driven upwelling is a mechanism for mantle decompression that does not require lateral density heterogeneity to drive upwelling. For example, vertical flow emerges at the edges of viscosity anomalies, if the asthenosphere is sheared horizontally [2]. These two ingredients are present in the SE Pacific, where (1) shear across the asthenosphere is inferred to be greatest worldwide [2], and (2) lateral variability in mantle viscosity is indicated by geoid lineations and anomalies in seismic tomography [3]. Eastward pressure-driven flow from the South Pacific Superswell has been suggested to break up into fingers thus providing this variability in viscosity [3].
Our three-dimensional numerical models [4] show that asthenospheric shear can excite upwelling and decompression melting at the tip of low-viscosity fingers that are propelled by vigorous sublithospheric flow. This shear-driven upwelling is able to sustain intraplate volcanism that progresses towards the MOR, spreads laterally close to the axis, and weakly continues on the opposite plate. These predictions can explain the anomalously-fast eastward progression of volcanism, and its spatial distribution near the EPR. Moreover, for a heterogeneous mantle source involving a fertile component in addition to peridotite, the predicted systematics of volcanism can account for the geochemical trend observed along the Pukapuka ridge, and the enriched anomaly of EPR MOR-basalt at 16°S-20.5°S. Our study highlights the role of horizontal asthenospheric flow and mantle heterogeneity in producing linear chains of intraplate volcanism independent of a (deep-rooted) buoyancy source.

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